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INSECT PARASITES AND PREDATORS OF INSECT PESTS

By CURTIS P. CLAUSEN, *senior entomologist, in charge, Division of Foreign Parasite Introduction, Bureau of Entomology and Plant Quarantine*

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INTRODUCTION

The insects usually noticed by those engaged in the growing of plants, whether farmers or gardeners, are the forms that feed upon the plants or plant products and are consequently injurious. There are, however, a very large number of insects that are entirely beneficial in their relation to crop production. This circular deals only with those species which, by preying upon or parasitizing other insects, aid in preventing damage to agriculture. In general, it may be stated that practically every insect in its native home has one or more species which prey upon it and are dependent upon it for their existence. Were it not for these parasites, many of our insect pests would be able to increase to such an extent that the growing of crops would be impossible. Insects have such an enormous capacity for increase that some very definite checks are necessary to keep them within bounds. When it is realized that some insects, such as the aphids, are able to complete a generation in a week or less, it is clear that they would very quickly become excessively abundant if no restraining influences were present. While climatic conditions are usually the most important factor in reducing the numbers of an insect pest, yet under suitable conditions the parasites and predators are of nearly as great importance. In most cases these factors prevent the plant-feeding insects from becoming excessively injurious, and only a very small proportion of these species of insects ever become sufficiently abundant to cause injury to crops.

This circular is intended to present a general account of the various forms of insects that prey upon or parasitize other insects. The

more common types encountered by plant growers are discussed, and general information is presented regarding their habits, the insects upon which they feed, and general descriptions by means of which they may be identified. For purpose of ready reference, these topics are dealt with under the primary headings of the insects that are attacked.

CONTROL OF INSECT PESTS BY PARASITES AND PREDATORS

In most cases when insect pests have gained entry into the United States they have not been accompanied by the parasites and predators which attack them in their native home. This being so, it is quite understandable that the pests have been able to increase to enormous numbers and to inflict great damage to crops. The importation of the parasites and other insect enemies is an effort to duplicate here the natural balance which exists in the former home of the insect.

The first attempt at the control of an insect pest by the importation of its predators from abroad was the importation of the vedalia beetle (*Rodolia cardinalis* Muls.) from Australia in 1888–89 to work against the cottony-cushion scale (*Icerya purchasi* Mask.) on citrus in California. Within a few years the scale was completely subjugated. This striking success led to further efforts along the same line, but it was many years before so decisive a result was again obtained. The most extensive program for parasite importation was that against the gypsy moth (*Porthetria dispar* L.) and the brown-tail moth (*Nygmia phaeorrhoea* Don.). The first shipments of parasites of these pests were received in 1905, and the work was continued until 1912 and then resumed during the period from 1922 to 1932. At the present time importations are being made of the parasites of a number of insects, such as the European corn borer (*Pyrausta nubilalis* Hbn.), the Japanese beetle (*Popillia japonica* Newm.), the oriental fruit moth (*Grapholitha molesta* Busck), and several forest insects. In general, it may be said that the importation of parasites from abroad is one phase in the attempted control of each of the most important foreign insect pests that have become established in this country.

There are certain definite limitations to the possibilities of control of insect pests by the use of parasites. Only in exceptional cases can complete control be achieved by this means. In the great majority of cases different degrees of partial control are secured. For this reason the introduction of parasites should be considered as supplementary to the usual methods of mechanical and chemical control rather than as a alternative method. The reduction in numbers of the insect pest by the use of parasites renders outbreaks less frequent, and control is then more readily accomplished by the use of sprays or other mechanical or chemical methods.

There are two distinct phases in the attempted control of an insect pest by the importation of its parasites. The first phase comprises the search for the parasites in foreign countries, the study of these to determine their usefulness, and finally their shipment to the United States; the second phase includes the rearing of the parasites and their distribution throughout the entire area infested by the pest in this country. It is obviously impossible to provide colonies of para-

sites for liberation on every farm or orchard, but the colonies are placed at such intervals that natural spread will soon provide a thorough distribution.

The foregoing statements apply entirely to the use of imported parasites. Various attempts have also been made, however, to extend the usefulness of the parasites native to this country. In some instances this has been done with marked success, but these instances have represented transfers of parasites from one part of the country to another to which their natural spread has been prevented by various physical barriers. In general, it may be stated that there is little possibility of securing increased effectiveness by the liberation of additional numbers of a parasite already present in a locality.

The natural enemies of various crop pests are often inconspicuous, and their presence is not detected by persons unfamiliar with them. Many inquiries are received from growers regarding outbreaks of field or orchard pests in which it is stated that the parasites are absent and that colonies are desired for liberation. To determine definitely the presence or absence of these parasites, the assistance of an expert from the State experiment station or from the Bureau of Entomology and Plant Quarantine may be required. Usually it will be found that the parasites are already present, though possibly only in small numbers. Local or temporary conditions may be unfavorable to them and, if so, the same handicaps will restrict the increase of any colonies that might be liberated. The Bureau of Entomology and Plant Quarantine does not maintain stocks of either native or imported parasites for general distribution to growers. The imported ones are colonized directly and in accordance with a definite plan of distribution.

ENEMIES OF APHIDS, SCALE INSECTS, AND MEALYBUGS

LADYBIRD BEETLES

The beetles of the family Coccinellidae, known variously as "ladybugs", "ladybirds", "ladybird beetles", or "lady beetles", are among the most common of all beneficial insects. Various species of these useful insects are widely distributed and often occur in enormous numbers. These beetles and their larvae feed upon a wide variety of insects, though more particularly upon aphids, scale insects, mealybugs, white flies, and red spiders. The various species do not feed indiscriminately, however, but each is more or less restricted to a particular insect or group of insects. Aphid-feeding species, for instance, do not generally attack scale insects, nor will feeders on mealybugs normally attack either scale insects or aphids. Several species are known to feed exclusively upon fungi, but these species are seldom encountered.

In this family there is one group, represented in this country by the genus *Epilachna*, which feeds exclusively on plant foliage and is consequently harmful. The best known example is the Mexican bean beetle (*Epilachna corrupta* Muls.), which was introduced into the Eastern States from the Southwest about 1920, has spread northward in recent years, and is now very injurious to the bean crop in most of the States east of the Mississippi River. The adult beetles of this species may be recognized by the form of the body, which is

more hemispherical than that of the common aphid-feeding beetles of the family, and by the copper-colored back, which bears 16 black spots.

The majority of the common aphid-feeding species are red and usually bear a variable number of black spots on the wing covers. The convergent lady beetle (*Hippodamia convergens* Guer.), illustrated in figure 1, is probably the one most frequently seen, particularly in the Western States. Nearly all species of aphids that do not bear a waxy covering are attacked by this beetle, which often plays an important part in checking aphid infestations.

The life histories of the beetles of this group are similar, and that of *Hippodamia convergens* is quite typical. The eggs are lemon yellow in color, spindle-shaped, and measure about one-twentieth of an inch in length. They are deposited in compact clusters of from 10 to 30 upon the foliage, usually among or near the aphid colonies, and each female may deposit as many as 1,000 eggs. Hatching takes place in about 5 days under summer conditions. The larva then feeds for about 16 days, and during this time it may eat from 200 to 500 aphids, as it is very active in its search for food. When full

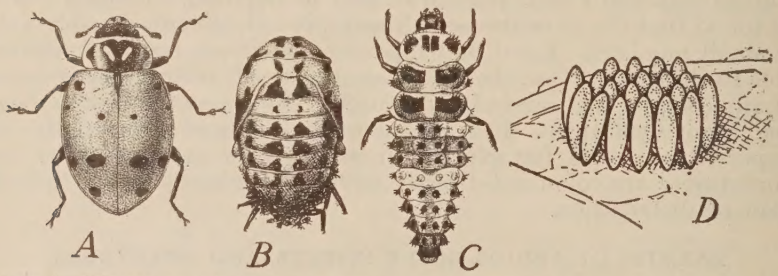

FIGURE 1.—The convergent lady beetle (*Hippodamia convergens*), a feeder on aphids: *A*, Adult beetle; *B*, pupa; *C*, mature larva; *D*, egg cluster. *A*, *B*, and *C*, about 4 times natural size; *D*, 8 times natural size.

grown it has a length of one-half inch. At the end of the feeding period the larva enters the resting or pupal stage and the compact body remains attached by its tip to the leaf surface or to any other object upon which it may rest. This resting stage covers from 6 to 7 days, after which the beetle appears and begins feeding immediately. Each beetle may consume a maximum of about 100 aphids per day during its active adult life. During early summer this may extend over from 1 to 2 months, and the beetles that appear later may survive the winter and resume feeding and egg laying in the spring.

The overwintering habits of this and related species are of particular interest. At the end of the season the beetles leave the fields and gardens where they have been feeding and migrate to mountain canyons, where they assemble in vast numbers upon low shrubbery and in rubbish; here they pass the winter, usually deeply covered with snow. A single colony, covering only a few square yards, may comprise a bushel or more of the beetles. These overwintering colonies are most numerous in California, though they are encountered in nearly all of the mountainous sections of the West.

The influences which bring about this assembling of beetles in such large colonies are not well understood, but it is not induced entirely by the lower temperatures of the fall months. Large col-

onies have been seen early in July massed upon rocks near streams and in bright sunlight, and in these instances the temperature of the rocks was certainly above 100° F.

A considerable number of species of ladybird beetles feed upon mealybugs, and the larvae of many of them bear a whitish waxy coating that gives them a resemblance to the insects upon which they feed. A few of the species that attack aphids, scale insects, and white flies also bear a similar covering.

One of the most effective of these beetles is the so-called "Australian ladybird beetle" (*Cryptolaemus montrouzieri* Muls.) which was imported into California from Australia in 1891–92 for the control of mealybugs attacking citrus in that State. Its life history differs from that of *Hippodamia convergens* in that the eggs are laid singly among the mealybugs, rather than in clusters, and the winter is passed in the resting stage in curled leaves and rubbish beneath the trees. This method of hibernation is a decided disadvantage to the species under the conditions existing in this country, as the fallen leaves decay, are blown away, or are plowed under during the winter. As a result, relatively few of the insects survive until the following spring. Because of this, the mealybugs are able to get a good start and become very abundant and injurious before the beetle is able to increase sufficiently to cope with them. This difficulty was overcome by the development, by the California State Department of Agriculture and the agricultural experiment station, of rearing methods whereby millions of the beetles could be produced at relatively low cost and liberated in infested citrus groves early each season. Effective control was thus obtained sufficiently early so that little or no damage was done by the mealybugs.

Another imported ladybird beetle of great value is the far-famed vedalia beetle (*Rodolia cardinalis* Muls.) (fig. 2), which, as previously mentioned, was imported into California from Australia in 1888–89 for the control of the destructive cottony-cushion scale (*Icerya purchasi* Mask.) on citrus. So rapidly did this beetle increase that within a few years this destructive scale ceased to be a pest, and to the present day it is of little or no consequence in the citrus groves. Occasionally a small infestation may appear, but this may be quickly eliminated by the liberation of colonies of the beetle. Usually, however, the beetles appear of their own accord. Following this remarkable success, the beetle was introduced into many other countries in which the cottony-cushion scale had become established, and in nearly every instance similar striking results were obtained.

Another importation from abroad is the Chinese ladybird beetle (*Chilocorus similis* Rossi), which was brought from Asia for use against the San Jose scale (*Aspidiotus perniciosus* Comst.). It was found in the orchards for a number of years after liberation but apparently did not become established. The adult beetles are shiny black and bear one red spot on the center of each wing cover, thus greatly resembling the twice-stabbed ladybird beetle (*Chilocorus bivulnerus* Muls.), which is native to this country and also feeds upon scale insects. The eggs are deposited singly among the scales or beneath the scale covering. The spiny larvae chew holes through the covers of large numbers of scales and feed upon the developing

insects. At the time of pupation the larvae of this and some other species of scale feeders have the habit of congregating in large colonies on favored twigs or on the branches or trunk of a tree (fig. 3). These colonies may contain several hundred individuals and are often conspicuous.

CONTROL OF APHIDS, SCALE INSECTS, AND MEALYBUGS BY THE LIBERATION OF LADYBIRD BEETLES

The fact that a number of serious insect pests have been fully controlled by the liberation of ladybird beetles has led to the belief

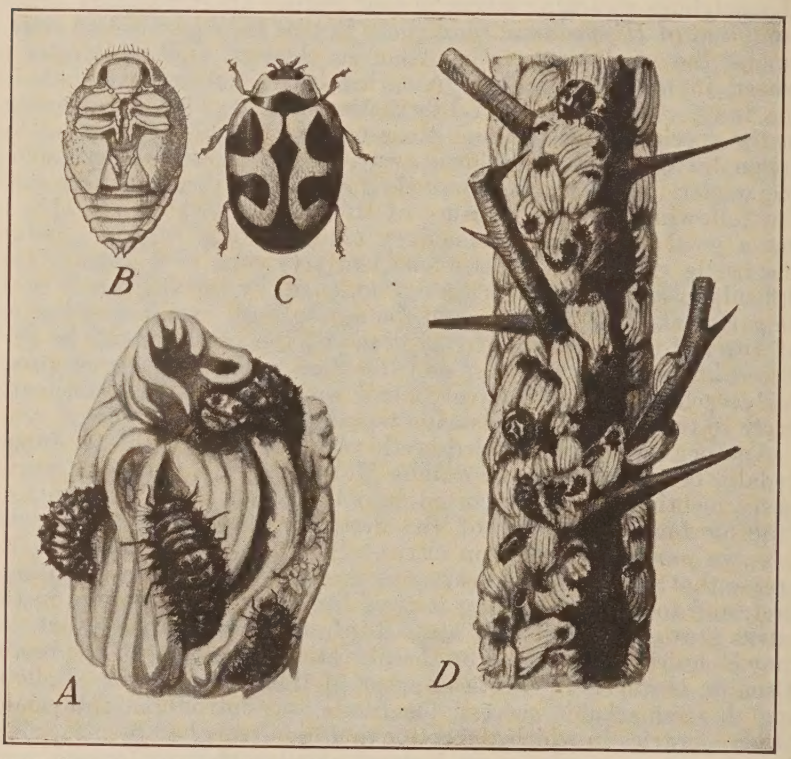

FIGURE 2.—The vedalia beetle (*Rodolia cardinalis*), an effective enemy of the cottony-cushion scale on citrus trees: *A*, Larvae feeding upon an egg mass; *B*, pupa; *C*, adult beetle; *D*, an infested twig showing eggs, larvae, and beetles among the scales. *A*, *B*, and *C*, × about 10; *D*, × 2.

among growers that many other farm, garden, and greenhouse pests can be controlled in the same way. This belief does not take into consideration the limitations of the different species as regards food habits, the conditions necessary for maximum increase, and other influences that control their effectiveness. The vedalia beetle, for instance, is effective only against the cottony-cushion scale, and its liberation in the hope of checking other pests cannot possibly be of any value. Likewise no control can be hoped for by the liberation of the convergent lady beetle upon trees infested with scale insects or mealybugs.

While the Australian ladybird beetle is very effective in controlling mealybug infestations under orchard conditions, it is of little or no value for use in greenhouses. The reason for this lies in the fact that a fairly heavy infestation is necessary before the beetle is able to increase rapidly. Orchard trees can stand this degree of infestation with relatively little injury, whereas greenhouse plants are seriously injured, or at least their market value is greatly reduced. The damage is done before the infestation becomes sufficiently great to permit of the increase of the beetle, and for this reason it is necessary to rely upon spraying or fumigation for control.

Many inquiries are received from residents in the mountainous sections of the West who have noted colonies of aphid-feeding lady-

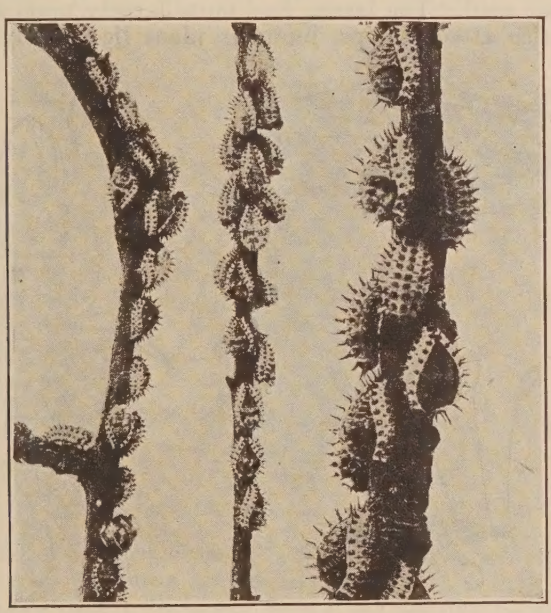

FIGURE 3.—Pupae of the Chinese ladybird beetle (*Chilocorus similis*) in typical clusters on twigs. Those at left are natural size.

bird beetles and wish to be advised as to a possible market for them. These beetles at present have no commercial value, although occasionally quantities are required for experimental purposes. This demand, however, is so small as to be negligible, and returns are seldom sufficient to defray the cost of collection and shipment. The presence of these beetles in such quantities in winter quarters indicates that they occur in large numbers in the orchards and fields in those sections during the spring and summer months. There is no advantage to be gained by the liberation of additional numbers in orchards where the beetles already occur. In general, these beetles appear in all sections in which the aphid infestations give them an opportunity to develop. The liberation of large colonies for the field control of aphid infestations is not recommended.

LACEWING FLIES

The lacewing flies are delicate, four-winged insects, so named because of the delicate tracery of their comparatively large, fragile wings. Their larvae are long-bodied, thickest in the middle section of the abdomen, and bear very long, sickle-shaped mandibles by means of which they seize and drain the body contents of their prey. Because of these formidable mandibles and the aggressiveness of the larvae in attack, they are often termed "aphis lions." There are two groups of these insects, the green lacewing flies (family Chrysopidae) and the brown lacewing flies (family Hemerobiidae).

The green lacewing flies (species of *Chrysopa* and related genera) (fig. 4) have the body and wings of a light greenish color and the eyes brilliant gold. The larvae feed quite largely upon aphids, but they may also attack thrips, jumping plant lice, mealybugs, scale

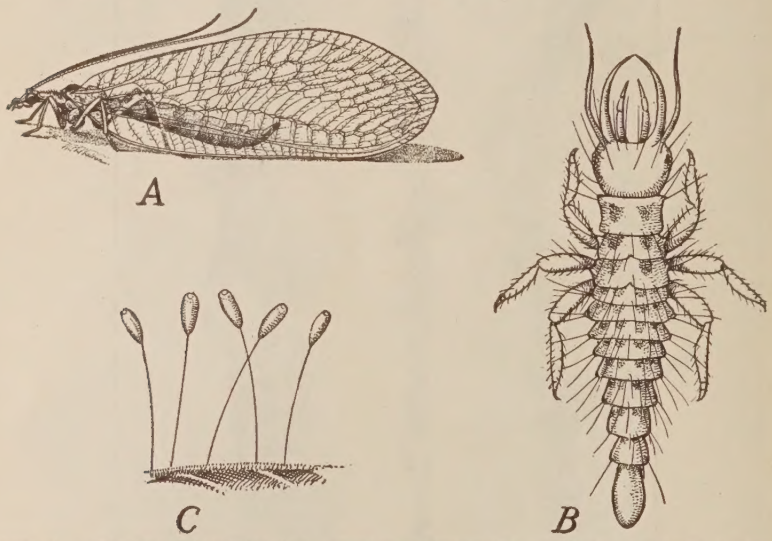

FIGURE 4.—*Chrysopa californica* Coq., a green lacewing fly; *A*, Adult lacewing; *B*, young larva; *C*, a group of stalked eggs upon a leaf. *A*, × 2½; *B*, × 9.

insects, red spiders, and the eggs of various insects. The eggs are green, about one-thirtieth of an inch in length, and are usually deposited singly upon the foliage. They are placed at the end of slender silken stalks one-fourth to one-half inch in length, an arrangement which is said to protect them from various enemies. Some species place the eggs in groups upon a single stalk or upon a bundle of fused stalks.

The larvae of many of the species of green lacewings have the very interesting habit of covering their bodies with packets of trash consisting of the shriveled bodies of aphids they have killed, molted skins, and other material, this debris being loosely woven together with silken strands. The body is often so completely covered by this packet that it is not visible except while in motion, when what appears to be a mere mass of trash proves to be the shelter borne by the lacewing larva.

The resting stage, which immediately precedes the appearance of the adult insect, is passed within a white, spherical, parchment-like cocoon formed in a curled leaf or in some other protected place.

The brown lacewing flies (species of *Hemerobius* and related genera) are similar in habit to the green lacewings mentioned above, but the body and wings of the adult are brown and the eyes lack the conspicuous golden color. The larvae do not carry the protective packet of trash, and they feed largely on aphids and mealybugs. The eggs are laid singly among the host insects and are not borne upon stalks. Many species pass the winter in the mature larval form in sheltered places rather than within the cocoon, as do the larvae of the green lacewings. The cocoon of the brown species is delicate,

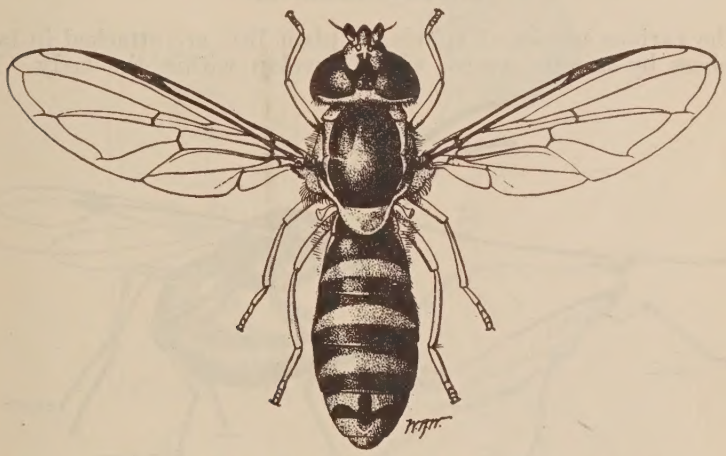

FIGURE 5.—The adult of *Sphaerophoria cylindrica* Say, one of the hover flies. × 7.

oval in form, and consists of a loose network of silken strands through which the pupa can readily be seen.

HOVER FLIES

The hover flies, of the family Syrphidae (fig. 5), are known to most growers as rather large, conspicuously marked flies with relatively long body and wings, which have a characteristic habit of hovering over the blossoms upon which they feed or over foliage infested with aphids. The adult flies feed upon honeydew secreted by aphids and scale insects and also upon the nectar of plants, whereas the larvae feed directly upon aphids and to a lesser extent upon other soft-bodied insects, such as mealybugs, immature leaf hoppers, and red spiders. Most of the aphid-feeding species may be found in greatest numbers in the field during the spring and early summer months.

The eggs are usually about three times as long as wide, and those of the larger species measure about one twenty-fifth of an inch in length. They are chalky white and consequently conspicuous when seen among the aphid colonies.

The larva, or maggot, is sluglike and usually has a mottled brown or green color. It moves slowly about the leaf in search of food, seizes the aphid prey, and sucks out the body juices. During its period of development each larva may consume up to 400 aphids, depending upon their size. The feeding period covers from 7 to 15 days.

The completion of feeding is followed by the resting, or pupal stage, during which the transformation to the adult fly takes place. The puparium, which encloses the insect while it changes to the adult form, is tear-shaped, brown or green in color, and is usually found among the aphid colonies where feeding took place or in sheltered places upon plants or on the ground.

INTERNAL PARASITES

The various species of aphids, or plant lice, are attacked in large numbers by minute wasps, which develop within the body. The

FIGURE 6.—An aphid parasite (*Lysiphlebus testaceipes*) in the act of stinging an aphid. The egg is inserted in the body at this time. × 15.

common grain aphid known as the "green bug" (*Toxoptera graminum* Rond.) is often heavily attacked by one of these (*Lysiphlebus testaceipes* (Cress.)) and under favorable conditions the pest is greatly reduced, often to the point where no further damage is inflicted. In many instances, however, this control comes relatively late in the season and after extensive damage has already been done. The same is true of the parasites of other aphids occurring on the different orchard, field, and garden crops.

The grain aphid parasite just referred to deposits its egg within the body of the aphid (fig. 6), and the adult wasp emerges 1 week later. The body contents of the parasitized aphids are entirely consumed, and the bodies assume a characteristic mummified condition (fig. 7, *B*) and adhere to the leaf surface. At times these mummified remains may be seen in enormous numbers upon the foliage; in fact, in far greater numbers than the healthy individuals. The mature wasps emerge from the body of the host aphid by cutting a circular lid in the body wall. The fact that the parasite completes a generation in from 7 to 10 days and that each adult may attack a total of 100

or more aphids makes possible an exceedingly rapid increase under favorable conditions.

In many sections the destructive woolly aphid (*Eriosoma lanigerum* Hausm.) of the apple is quite effectively controlled by *Aphelinus mali* Hald. Usually the parasites occur normally in the field where the aphid host is found, and climatic conditions largely determine the extent to which they are able to increase.

Practically all species of scale insects and mealybugs are attacked by minute wasps which develop within the body. Individual scale

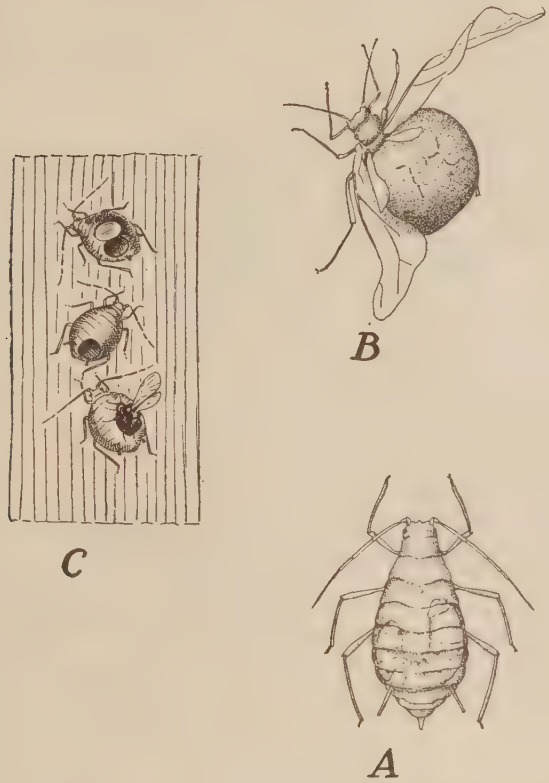

FIGURE 7.—Grain aphids parasitized by the wasp *Lysiphlebus testaceipes: A*, An aphid showing the parasite larva within the body; *B*, a dead, mummified aphid; *C*, a parasite emerging from an aphid, and two aphid bodies showing the typical emergence holes. *A* and *B*, × 12.

insects can normally be recognized as parasitized only after the adult parasite has emerged, leaving its exit hole, for when the wasp reaches maturity it chews a small circular hole through the upper side of the scale sufficiently large to permit its escape. In heavy infestations of the soft brown scale (*Coccus hesperidum* L.) and the black scale (*Saissetia oleae* Bern.) on citrus, the San Jose scale on apple, and various others, a very large proportion of the scales may be found dead because of parasite attack and showing these characteristic holes in the body wall.

Parasitized mealybugs are readily recognized by a swollen, mummified condition. The parasite undergoes its transformations within this hardened shell and finally gnaws its way out. Of the parasites of mealybugs and scale insects, the majority of the species develop singly, yet even among these some may develop to the number of several dozen in a single host insect.

PARASITES OF CATERPILLARS

The caterpillars (larvae of butterflies and moths) and beetle and sawfly larvae which feed upon the foliage of plants and those which bore into the twigs and trunks of trees are attacked by a wide variety of other insects. Among them are the parasitic flies, which develop within the body of the host, and various wasps, which sting the caterpillars and deposit their eggs either in or on the body.

Nearly every species of caterpillar is attacked by one or more species of tachinid flies, most of which bear a considerable resemblance to the house fly but may be much larger. The flies of this entire group, and others as well, are beneficial rather than harmful. The majority of these flies lay their eggs upon the body of the caterpillar, where they may be recognized as white oval spots one twenty-fifth of an inch or less in length. Caterpillars may often be seen bearing many of these eggs, in exceptional cases as many as 50 to 100. Whether only one or many eggs are laid on a caterpillar, generally only a single parasite develops to maturity, though in one instance 80 were reared from a single individual.

The egg hatches within a few days after being laid, and the minute maggot bores through the skin into the body. Here it feeds upon the blood of the caterpillar, and after a variable period of time completes its feeding upon the body contents and emerges. It then enters the resting stage, usually in the soil, in a puparium which is quite similar in appearance to that of the house fly and the stable fly.

The small *Apanteles* wasps are frequently very effective in destroying caterpillars. The cocoons of the parasites of this group are often seen upon foliage and are conspicuous because of the large number that may occur in each mass and by their white or yellow color. In some species the cocoons are found singly, but in others they occur in clusters of from 25 to 50 or more and are often covered with a loose mass of silk. These cocoons may be formed directly upon the body of the caterpillar (fig. 8) from which the larvae emerged, or they may be scattered irregularly about it upon a leaf, or in orderly tiers one above the other like rows of bricks. An instance is recorded of more than 1,000 of these parasites emerging from a single caterpillar. Many inquiries are received regarding these cocoon masses, and they are often mistaken for insect eggs and consequently destroyed.

One of the most common species of this group is *Apanteles glomeratus* L., which attacks the imported cabbage worm (*Ascia rapae* L.). The female wasp stings the very young caterpillars and lays from 15 to 50 eggs within the body. The larvae feed upon the body fluids for about 2 weeks and then emerge by cutting individual holes through the skin of the still-living, nearly full grown caterpillar, which may not die for several days. All of the larvae contained in

a single caterpillar emerge from it on the same day. The cocoons are spun upon the foliage nearby. The cocoon stage covers about 5 days, and the adult wasp then emerges by cutting away a circular cap from one end.

There are many other kinds of wasps that attack caterpillars. These may attack the caterpillar directly during its feeding period or they may attack the larva or pupa in the cocoon. Some of these wasps are so small that several thousand may develop in each caterpillar, but as a rule only one matures. Often a collection of chrysalids or cocoons will yield large numbers of these parasitic wasps and flies instead of the butterflies and moths that were expected.

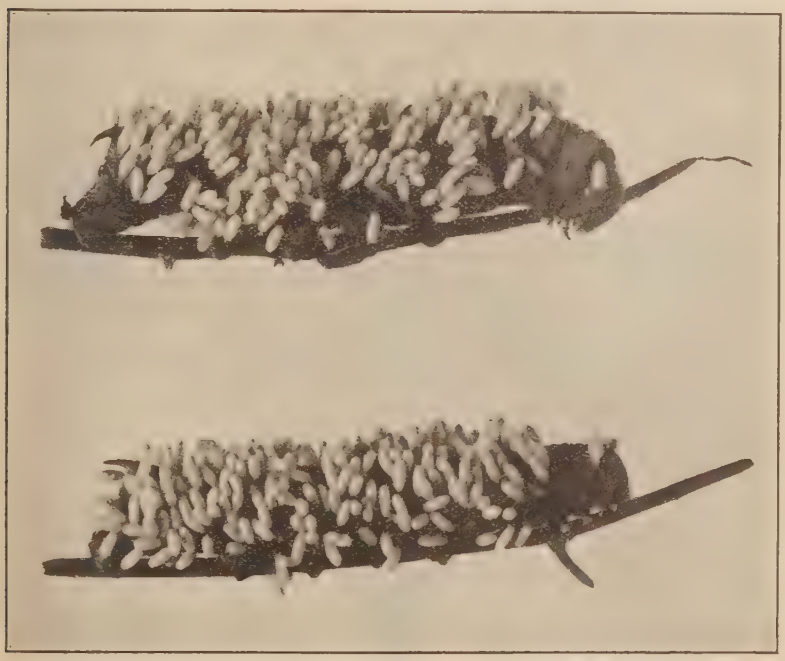

FIGURE 8.—Cocoons of the wasp *Apanteles congregatus* L. upon the tobacco hornworm. Natural size.

Among those parasites that develop in considerable numbers in one host is a group which has the remarkable habit of producing many individuals from one egg. A single egg is laid in the host egg, but development is delayed until the latter hatches and the larva begins to feed and grow; then the parasite egg grows and divides repeatedly, and finally may give rise to hundreds of individuals. Instances are known of several thousand minute wasps developing in this way in a single caterpillar.

PARASITES OF WHITE GRUBS

The white grubs found so commonly in the soil and which feed upon the roots of grasses and cultivated crops are the larvae of beetles known as "June bugs", "May beetles", etc. When these

grubs are exposed by plowing during the summer months they are often found to bear larvae of some other insect attached to the body, or the soil cells which they had occupied contain instead brownish-colored, oval cocoons measuring from one-half to 1 inch in length. Only the head and a portion of the skin remain to identify the original occupant. The insect responsible for the death of the grubs is one of the digger wasps, so called because of their habit of digging burrows in the ground or wood to make nests for their young, or in search of prey.

As typical of this group *Tiphia popilliavora* Roh. (fig. 9), which attacks the grubs of the Japanese beetle (*Popillia japonica* Newm.),

FIGURE 9.—The adult female of the black digger wasp *Tiphia popilliavora*. × 6.

may be mentioned. This wasp is jet black, with dusky wings, and measures about two-thirds of an inch in length. It appears in the field late in August and in September, and may be found feeding upon the blossoms of wild carrot, smartweed, and other plants. When the time for egg laying arrives, the female enters the soil in search of grubs, and when one is found it is stung until completely paralyzed and the egg is then laid on the underside of the body. The grub recovers its powers of movement within about half an hour and resumes feeding. The young wasp larva, immediately after hatching, makes a feeding puncture through the skin of the grub and sucks out the body juices. This feeding continues for 2 weeks or more, and during this time the white parasite larva may be seen lying across the abdomen of the grub (fig. 10, *B*). The beetle grub

gradually becomes weakened by the feeding of the parasite and finally dies.

Other species of this group may emerge during the spring months, and the adults feed upon the honeydew secreted by aphids and various other insects. Some species, such as the banded digger wasp (*Elis quinquecincta* Fab.), paralyze their prey permanently, but these seemingly lifeless grubs are seldom encountered, because the parasite female usually buries the grub to a depth of 1 or 2 feet or more before laying the egg upon it. Grubs parasitized by *Tiphia*, and the cocoons which are formed later, are usually found near the surface of the soil.

In addition to the wasps mentioned above, a number of parasitic flies attack white grubs. The young maggots are deposited upon the surface of the ground; they then penetrate the soil in search of grubs upon which they may develop. When such a grub is found,

FIGURE 10.—Two parasites of white grubs: *A*, A maggot of the fly *Prosena sibirita* completing feeding upon a grub; in its earlier stages it fed within the body of the living grub. *B*, A half-grown larva of the black digger wasp, *Tiphia popilliavora*, feeding upon a Japanese beetle grub. *A*, × 4; *B*, × 3.

the maggot enters the body and feeds upon the juices. The adult flies are found in the field during midsummer. Typical of this group are *Microphthalma disjuncta* Wied., which attacks the common white grubs infesting field and pasture lands in the Middle West, and *Prosena sibirita* (Fab.) (fig. 10, *A*), which attacks the grubs of the Japanese beetle.

EGG PARASITES

Large numbers of insect eggs are destroyed by minute parasites which develop in them, and some of these egg parasites are so small that nearly 100 may reach maturity in each of the eggs of the larger moths. The adult wasps of these species may measure only one twenty-fifth of an inch or less in length.

The best known of the species which confine themselves entirely to insect eggs is *Trichogramma minutum* Riley (fig. 11), which is usually yellowish in the South, nearly black when found in the

northern regions, and has large red eyes. This parasite is known to attack the eggs of more than 150 species of insects, including those of leaf hoppers, sawflies, butterflies, and moths.

The female *Trichogramma* wanders about upon the foliage in search of eggs which she may attack. When these are found, she climbs upon each one in turn, inserts the sting through the shell, and

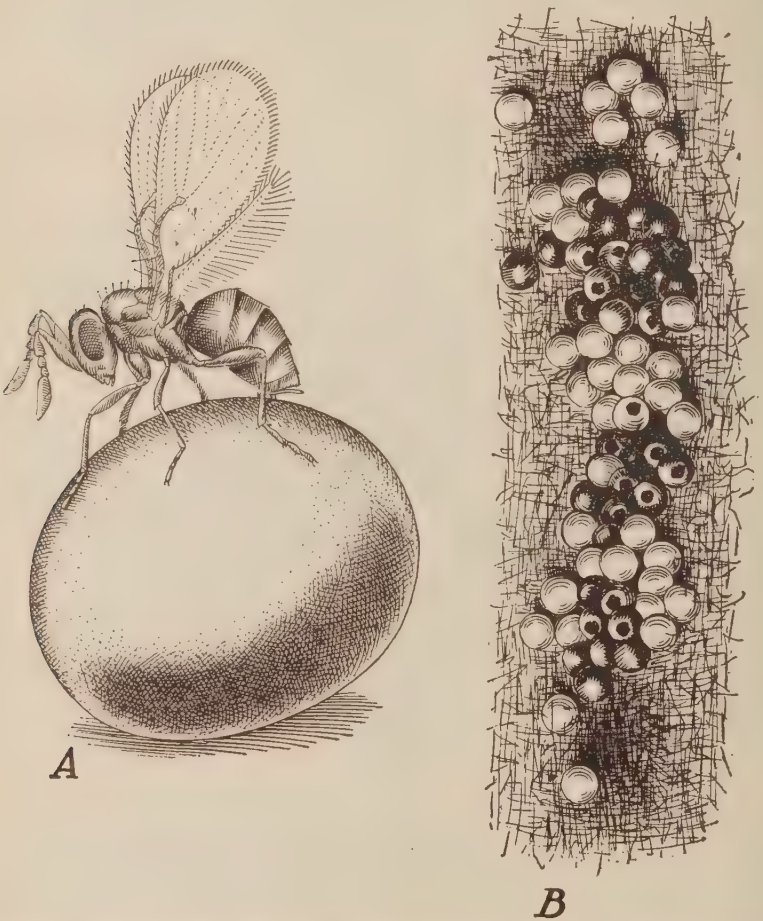

FIGURE 11.—*Trichogramma minutum*, a parasite of insect eggs: *A*, A female stinging a moth egg and placing its own egg within it; *B*, a cluster of eggs, of which about half have been parasitized and show the *Trichogramma* emergence holes. *A*, × 35.

deposits an egg within it. The development of the larva is very rapid under summer conditions, and the entire life cycle may be completed in 1 week. It is thus seen that an exceedingly rapid increase in numbers is possible. During the summer and early fall months more than 90 percent of the eggs of many species of insects may be destroyed by this parasite, and consequently it plays an important part in holding various pests in check.

In recent years efforts have been made to extend the usefulness of this parasite by rearing the species in enormous numbers upon grain moth eggs and liberating them in the infested fields and orchards early in the season. This has been tried on a number of important pests of field crops and orchard trees, but the results thus far have not been conclusive. This work is still in the experimental stage, and at present it is not recommended to growers as a field practice.

In addition to *Trichogramma*, many other species of minute wasps parasitize the eggs of moths, butterflies, beetles, and plant bugs. Two species, which attack the eggs of the gypsy moth, have been

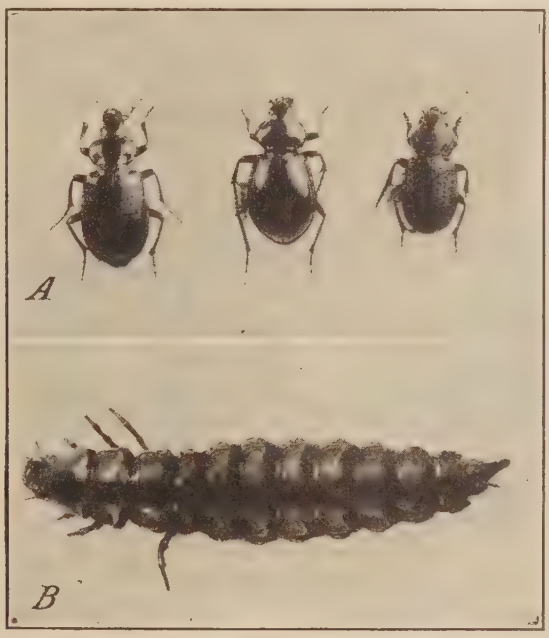

FIGURE 12.—*A*, Several species of ground beetles of the genus *Calosoma*, about natural size; *B*, a typical ground beetle larva, enlarged about three times.

imported from Japan and one of them also from Europe, and are now well established in this country.

GENERAL INSECT FEEDERS

There is a wide variety of insects which, in either the larval or adult stage, have the habit of feeding upon such soft-bodied insects as they may encounter. Among these are the ground beetles, the tiger beetles, the robber flies, and a number of common plant bugs.

The ground beetles of the family Carabidae (fig. 12) and their larvae feed upon many kinds of insects. The adult beetles are found mainly upon the surface of the ground, though some climb trees; the larvae are generally found either in the soil or beneath rubbish, but a few of these also climb trees in search of their prey.

The green *Calosoma* (*C. sycophanta* L.), which attacks the gypsy moth, the brown-tail moth, and others is of considerable importance in checking these pests. This species was imported from Europe in 1905–10 and is now found in practically all sections infested by the gypsy moth. The eggs are laid singly in the soil, and the larvae, immediately after hatching, begin their search for food, which consists largely of the caterpillars and pupae of butterflies and moths. These may be found on the surface of the ground or in rubbish, or it may be necessary for the *Calosoma* larvae to climb trees and bushes to find them. When the prey is found it is seized between the mandibles, a hole is cut in the skin, and the body juices and other materials are eaten. A total of 40 or more full-grown gypsy moth larvae may be consumed by a *Calosoma* larva during its period of development, which covers from 2 to 4 weeks. The adult beetles feed largely upon caterpillars and consequently spend considerable time in the trees. The beetle spends the winter in a cell in the soil, and its life may extend over more than 2 years.

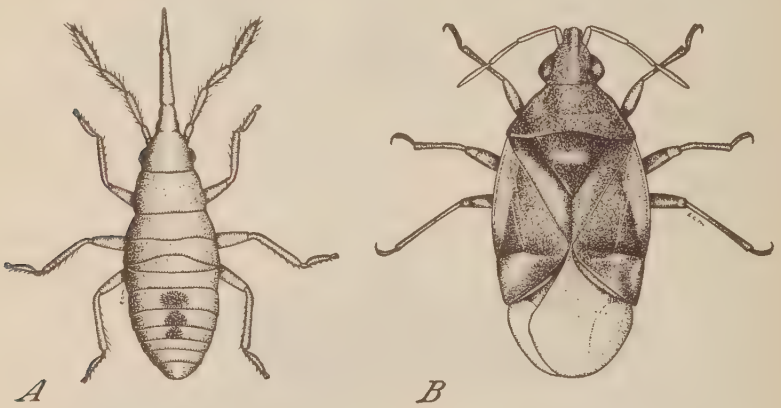

FIGURE 13.—*Orius insidiosus*, a predacious flower bug: *A*, Nymph, × 50; *B*, adult, × 15.

The tiger beetles (Cicindelidae) are usually found in dry and sandy places. Their larvae build funnel-shaped pits in the soil and lurk therein while awaiting their prey. They will eat almost any insect that has the misfortune to come within reach of their formidable mandibles.

While a majority of bugs, such as the harlequin bug (*Murgantia histrionica* Hahn), are plant feeders and consequently injurious, some species are of real value because of the number of plant-feeding insects which they destroy. There are a considerable number of common bugs, such as the assassin bugs (Reduviidae), the flower bugs (Anthocoridae), the ambush bugs (Phymatidae), and some of the stinkbugs (Pentatomidae), which feed extensively upon the eggs, larvae, and adults of various insects, and they are often of considerable value in reducing infestations. The common flower bug (*Triphleps*) *Orius insidiosus* (Say) (fig. 13) occurs throughout the United States and feeds largely upon other insects. It has been recorded as attacking the eggs and larvae of the corn ear worm (*Heliothis obsoleta* Fab.) and is said to be one of the most important of the

natural enemies of that insect. This bug is also known as an important enemy of the European red mite (*Paratetranychus pilosus* C. and F.) upon fruit trees, the common red spider (*Tetranychus bimaculatus* Harv.) on cotton, hops, and citrus, and of various species of thrips. Aside from its insect-feeding habits it has been associated with the transmission of certain diseases of corn.

Various bugs may at times be found with the beak imbedded in the body of a caterpillar, from which they suck out the body juices. Some of these species confine themselves to insect food while others may subsist upon a mixed diet of insect and plant juices.

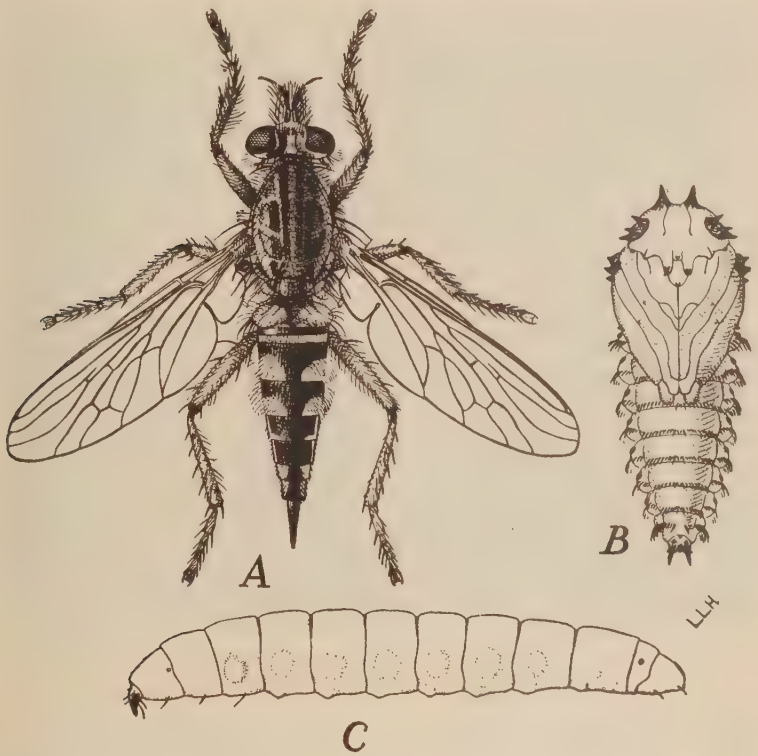

FIGURE 14.—*Erax lateralis* Macq., a robber fly: *A*, The adult fly; *B*, the pupa; *C*, the active larval form. × 3.

The robber flies (fig. 14), which belong to the family Asilidae, feed very extensively upon a wide variety of insects. Many of them are large, powerful flies, capable of capturing beetles, flies, and other insects while in flight. After seizing their prey they insert the beak into the body and suck out the juices. The larvae of these flies live in the soil and feed upon white grubs and other soft-bodied insects. In appearance the larvae have a considerable resemblance to the wireworms that feed upon the roots of plants.

The praying mantids are large, conspicuous insects which attract much attention because of the striking manner in which the front legs are held while awaiting prey. The forelegs are long and armed with

rows of teeth, by means of which the prey is grasped. In the waiting position these legs are held raised and folded and give the appearance of an attitude of prayer. The native species (*Phasmomantis carolina* Joh.) illustrated in figure 15, occurs commonly in the southeastern part of the United States.

Two species are now becoming increasingly common in the Northeastern States, these being the Chinese mantis (*Paratenodera sinensis* Sauss.), accidentally introduced from Japan about 1896, and the European praying mantis (*Mantis religiosa* L.), likewise accidentally introduced into this country about 1899.

FIGURE 15.—A partly grown praying mantid, *Phasmomantis carolina*, in the typical waiting position upon a twig. About natural size.

The various species of mantids feed on a wide variety of insects, including beetles, flies, aphids, and almost any others that come within reach. They normally frequent flowers in search for food, and consequently the flower-feeding insects comprise a large portion of their prey. Studies have been made of the food habits of the Chinese mantis, and these show that, while a great many injurious insects are eaten, the insect most commonly captured is the honeybee. To this extent, at least, the mantids may be considered as injurious rather than beneficial.

The eggs are laid in large masses upon twigs of trees and upon briers and grasses. They are covered with a mass of frothy material which hardens to form a tough, protective covering. These masses are conspicuous and are often seen during the winter.

HYPERPARASITES

The term " hyperparasite " is applied to that group of insects which attack the true parasites themselves rather than the insect species which cause injury to crops. They are thus injurious rather than beneficial. As has already been stated, practically every injurious insect has one or more primary parasites. Likewise these latter also have their enemies which attack them. In nature this usually brings about a balanced condition in which both the pest itself and the parasites which attack it are able to exist, but neither becomes overabundant.

If a cluster of cocoons of *Apanteles* spun by larvae that have developed in the cabbage worm, the tobacco hornworm, the gypsy moth, or any other of the numerous victims of this group of parasites, is set aside for emergence it will often be found that a variety of minute wasps rather than a single species will emerge from them. These are the enemies of *Apanteles*, which have attacked the larvae in the cocoons. From the puparia of the various fly parasites of caterpillars, from those of hover flies, and from lacewing cocoons, wasps will often emerge instead of the insects expected. There is thus revealed a complicated relationship among the insects themselves which results in a balance under natural conditions. This, however, is often upset by the changes brought about by man. Instead of a varied vegetation, large tracts of land are brought into cultivation and devoted to a single crop, frequently one which is new to the country. The resulting conditions have a marked effect upon the insect life of that section and often result in disastrous outbreaks.

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